REQUEST FOR A SPECIAL PROJECT 2013–2015

MEMBER STATE: Germany

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Project Title:

The impact of fluctuations of temperature, humidity and wind on cirrus clouds

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP**DEISSR (aka SPDEFLUC)	
Starting year: (Each project will have a well defined duration, up to a maximum of 3 years, agreed at the beginning of the project.)	2012	
Would you accept support for 1 year only, if necessary?	YES X	NO ☐

Computer resources required for 2013-2015: (The maximum project duration is 3 years, therefore a continuation project cannot request resources for 2015.)	**2013**	**2014**	**2015**
High Performance Computing Facility (units)	300 000	300 000	
Data storage capacity (total archive volume) (gigabytes)	200	200	

*An electronic copy of this form **must be sent** via e-mail to:* *special_projects@ecmwf.int*

Electronic copy of the form sent on (please specify date): 27 April 2012

Continue overleaf

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide an annual progress report of the project's activities, etc.

Principal Investigator: Dr. Klaus Gierens

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Extended abstract

It is expected that Special Projects requesting large amounts of computing resources (500,000 SBU or more) should provide a more detailed abstract/project description (3-5 pages) including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used. The Scientific Advisory Committee and the Technical Advisory Committee review the scientific and technical aspects of each Special Project application. The review process takes into account the resources available, the quality of the scientific and technical proposals, the use of ECMWF software and data infrastructure, and their relevance to ECMWF's objectives. - Descriptions of all accepted projects will be published on the ECMWF website.

In a study of "instantaneous fluctuations of temperature and moisture in the upper troposphere and tropopause region", Dotzek and Gierens (2008) wrote the following sentences:
"The atmosphere is an open thermodynamic system with highly variable forcing, in particular from solar radiation above and from orographic and topographic effects below. The forcing varies on diurnal, seasonal and longer timescales, as well as geographically due to the relative location of the sun and the non-uniform distribution of land and sea. The atmosphere reacts in a number of large- and small-scale circulation patterns. Additionally, there are atmospheric tides caused by gravitational interaction with both sun and moon [...]. Consequently, the air is never fully at rest, which always leads to a general background of small variations of the atmospheric state variables in any one place, in particular for temperature and relative humidity. However, occasionally larger fluctuations can appear in the state variables. Fluctuations that occur only rarely in space and time are called intermittent."
Dotzek and Gierens (2008) discuss then possible physical processes that lead to fluctuations, e.g. gravity waves, shear instabilities, ice supersaturated regions (colder and moister than their environment, e.g. Gierens et al. 1999, Spichtinger et al. 2003), tropopause folds, deep convection, air mass boundaries (upper level fronts), and clear air turbulence.
Not surprisingly, the statistical properties of the mentioned fluctuations (Gierens et al. 2007) are better known then the processes that cause them. The present proposal aims at further progress in the understanding of the involved processes and how they impact atmospheric variability. A major focus is also laid on the impact of these fluctuations on clouds, as it was quite from our early studies in this subject (Gierens et al. 1997) a major goal, to provide ideas and data for the modelling of unresolved processes (like clouds) in large-scale models.
A list of questions that we will work on is:

- Which are the processes that cause fluctuations of T, RHi, and w (or omega) in the upper troposphere?
- Are there signatures in meteorological data that signify the action of a certain process?
- How do these processes affect the statistical properties of the T, RHi, and w fields?
- How can true random fluctuations be distinguished from large-scale (synoptic) patterns?
- What are the spatial and temporal scales involved in the fluctuations caused by different processes? (Autocorrelation lengths and times).
- How do various processes affect the tails of the fluctuation pdfs? Are there signatures of intermittency?
- How do fluctuations affect cloud (in particular cirrus cloud) formation, evolution, and properties and how does this affect radiation transfer in clouds.
- And vice versa: how do clouds act on these fields? Are there characteristic differences of random fields between clear sky and cloudy cases?
- Do clouds trigger/enhance or dampen fluctuations?

To answer these questions we will combine data analysis and (cloud resolving) numerical simulations. Meteorological data will be taken mainly from ECMWF's Mars archive (and to have access to this is the main reason for this proposal).

Meteorological analyses only cover a certain range of scales, i.e. they can be used for identification of processes on scales larger than about 10km. For extending our investigations to the scale below 10km, investigations with models are necessary. Here, we can prescribe typical but idealized conditions in order to investigate the impact of different processes on relevant scales on the signatures of fluctuations. We will investigate the occurrence of fluctuations in thermodynamical and dynamical fields for typical meteorological conditions as:

- Frontal systems, especially idealized warm fronts
- (Orographic) gravity waves
- Turbulence induced by breaking gravity waves

In much more idealized simulations we will investigate the impact of dynamics, i.e. wind shear and static stability, on the time evolution of fluctuations. Additionally, we will investigate the possible impact of (cirrus) cloud processes on these fluctuations.

For this purpose the anelastic non-hydrostatic model EULAG (Prusa et al., 2008) together with a recently developed ice microphysics scheme (Spichtinger & Gierens, 2009a) will be used for high-resolution simulations (dx~100m, dz~10-50m). This model was used for several investigations of cirrus clouds in different meteorological situations; these data sets can be used for first investigations (e.g. Spichtinger & Gierens, 2009b; Joos et al., 2009; Spichtinger & Smolarkiewicz, 2008). However, we will have to study some effects in details, thus we will carry out new simulations. Additionally, we can make use of the new method of transient ambient states (Fusina et al., submitted). This method enables us to prescribe a time-dependent large-scale flow in the model (i.e. a full solution of the anelastic equations) in order to investigate the impact of a fully controlled dynamics on the smaller scales, especially on small scale fluctuations. Optionally, a simple but fast radiative transfer scheme implemented in the EULAG model (Fusina & Spichtinger, 2010) can also be used in order to investigate possible impact of diabatic processes on fluctuations.
The EULAG model is currently running on the HPC system of ECMWF. The model itself can be run highly parallelized on many hundreds to thousands CPUs without losing its scaling properties.

Our proposed work has strong connections to other research fields, namely the life cycle of cirrus clouds in the upper troposphere, stratosphere-troposphere exchange and diabatic mixing processes in the atmosphere.

ECMWF will benefit from our proposed work in the following ways:

- We will hopefully improve our understanding of processes leading to variations in thermodynamical and dynamical fields and their impact on processes on different scales.
- We will obtain better knowledge about important processes for generating fluctuations on scales which are not resolved in the IFS up to now
- We will obtain further information for possible parameterisations of such unresolved but nevertheless important processes

References

Dotzek, N., K. Gierens, 2008: Instantaneous fluctuations of temperature and moisture in the upper troposphere and tropopause region. Part 2: Structure functions and intermittency. Meteorol. Z., 17, 323-337.

Fusina, F. and P. Spichtinger, 2010: Cirrus clouds triggered by radiation, a multiscale phenomenon. Atmos. Chem. Phys., 10, 5179-5190, doi:10.5194/acp-10-5179-2010.

Fusina, F., P. Spichtinger, A. Dörnbrack: Cirrus clouds formed by a time dependent flow over a mountain. submitted to J. Atmos. Sci.

Gierens, K.M., U. Schumann, H.G.J. Smit, M. Helten, G. Zängl, 1997: Determination of humidity and temperature fluctuations based on MOZAIC data and parametrization of persistent contrail coverage for general circulation models. Ann. Geophys. 15, 1057-1066.

Gierens, K., U. Schumann, M. Helten, H.G.J. Smit, A. Marenco, 1999: A distribution law for relative humidity in the upper troposphere and lower stratosphere derived from three years of MOZAIC measurements. Ann. Geophys. 17, 1218-1226.

Gierens, K., R. Kohlhepp, N. Dotzek, H.G.J. Smit, 2007: Instantaneous fluctuations of temperature and moisture in the upper troposphere and tropopause region. Part 1: Probability densities and their variability. Meteorol Z., 16, 221-231.

Joos, H., P. Spichtinger, U. Lohmann, 2009: Orographic cirrus in a future climate. Atmos. Chem. Phys., 9, 7825-7845.

Spichtinger, P., K. Gierens, W. Read, 2003: The global distribution of ice-supersaturated regions as seen by the Microwave Limb Sounder. Q. J. R. Meteorol. Soc., 129, 3391-3410.

Spichtinger, P. and K. Gierens, 2009a: Modelling Cirrus Clouds. Part 1a: Model description and validation. Atmos. Chem. Phys., 9, 685-706.

Spichtinger, P. and K. Gierens, 2009b: Modelling Cirrus Clouds. Part 1b: Structuring cirrus clouds by dynamics. Atmos. Chem. Phys., 9, 707-719.

Spichtinger, P. and P. K. Smolarkiewicz, 2008: Turbulence in cirrus clouds. 15th Conference on Clouds and Precipitation. Cancun, Mexico. 7-11 July 2008. (extended abstract)